Visit Suncam.com for more courses

Continuing Education Course #402
External Ballistics Primer for Engineers
Part I: Aerodynamics & Projectile Motion

1. Ballistics is broken into three generalized categories. What are they?
- a. Deformational, Permutational, Oscillational
- b. Altitudinal, Latitudinal, Longitudinal
- c. Internal, External, Terminal
- d. Vernal, Autumnal, Estival

2. A toy rocket is dropped (straight down with zero initial velocity) from the ledge of a 60 m tall building. Assuming gravity is the only *force* acting on the rocket, how long will it take it to impact the ground? You can use the course's accompanying spreadsheet, *Projectile Motion* tab, or the following equation to answer the question. Equation: $y_0 = \frac{1}{2}gt^2$, where y_0 is the initial height, g is earth's acceleration due to gravity near the surface (approximately 9.81 m/s²), and t is the amount of time in seconds that the rocket will be in flight.
- a. 3.5 s
- b. 13.5 s
- c. 1.2 s
- d. 22.1 s

3. Why is it that projectile motion equations cannot very accurately describe the motion of many ballistic projectiles?
- a. Both answers C & D are true.
- b. Horizontal gravitational forces are not considered.
- c. Projectile motion only concerns itself with gravitational effects and treats no other potential flight path modifiers such as drag.
- d. Projectile motion treats all possible flight path modifiers, so this question is not valid.

4. At what approximate distance, in kilometers, from the surface of the earth does the acceleration due to gravity drop to about 1 m/s²? You may refer to the accompanying spreadsheet (Gravity tab) for a quick determination of this value, or use equation 1 of the primer.
- a. 100,000 km
- b. 13,590 km
- c. 1,360 km
- d. 100 km

5. Similar to a helicopter in the troposphere being able to hover at a given location, the top secret X72A spacecraft is able to maintain any distance above any location on a planet's surface (no need for orbiting the planet/satellite). Terry the flight engineer, of 200 lbm (give or take...), is seated in the vehicle. When standing, how much force is Terry exerting against the floor at 250 miles above earth? What about 250 miles above the surface of the moon? The mass and mean radius of the moon are 1.6199e23 lbm and 1079.57 miles respectively.
- a. 82.2 lbf & 45.1 lbf
- b. 180 lbf & 180 lbf

○ c. 185.4 lbf & 252.1 lbf
○ d. 159.3 lbf & 19.7 lbf

6. Generally speaking, there are only two **CAUSES for aerodynamic forces** acting on a projectile in ballistic flight, what are they?
○ a. Lift & Drag
○ b. Skin Friction Drag & Form Drag
○ c. Surface Pressure & Surface Shear Stress
○ d. Drag Coefficient & Ballistic Coefficient

7. Through experimentation Chutin' Starz engineers designed and extensively tested a new star shaped parachute with a calculated drag coefficient of 1.23 under the conditions in which the parachute was designed for. Their biggest selling parachute, which is also their original design, has a roughly rectangular projected shape and an estimated drag coefficient of 1.11 under the similar conditions. All else being equal, which of the two would be a better selection for a skydiver wishing to travel slower when the chute is fully deployed/inflated?
○ a. Obviously he should select the more esthetically appealing one since that's more important than drag coefficients anyway.
○ b. The one with the higher drag coefficient (1.23), i.e. the star
○ c. The one with the lower coefficient of drag (1.11), i.e. the rectangular
○ d. Neither, use a much smaller *pilot chute* instead.

8. Relative humidity is measured on two samples of air at the same temperature and atmospheric pressure. One of the two has a higher humidity than the other. The increased water vapor content has what effect on air density of the sample and hence the strength of the effect wind has on a ballistic projectile?
○ a. Increasing humidity increases air density
○ b. Increasing humidity has no effect on air density
○ c. Increasing humidity decreases air density
○ d. No enough information is given to make a determination

9. At 85,300ft MSL, what is the approximate average air temperature?
○ a. -64.3°C
○ b. 300.2°R
○ c. 300.2K
○ d. -64.3°F

10. What would likely be the most similar B.C. drag model for a 7.5° boat-tail bullet with a 9 calibers tangent ogive?
○ a. G1
○ b. G2
○ c. G5
○ d. G7

11. Pure carbon dioxide gas has a gas constant, R, of 35.11 $\frac{ft - lb_f}{lb_m - {}^\circ R}$ and a ratio of specific heats of 1.279. At a temperature of -40 °F, what is the speed of sound through CO_2 in ft/s? When working in US customary units don't forget the g_c multiplier of 32.174 lbm-ft/lbf-s_2.
○ a. 2121 ft/s
○ b. 779 ft/s
○ c. 880 ft/s
○ d. 95 ft/s

12. The pilot of a bright yellow Piper J-3 Cub is making her approach into Chicago O'Hare (ORD). The Cub is fitted with a pitot tube which is measuring 14.56 psig and a static pressure tap on the wall of the fuselage which is measuring

14.21 psig. The ambient air temperature is 80 °F and has a density of .0765 lb_m/ft^3. Assuming all the pilot's readings are accurate, what is the calculated pressure velocity of the plane per equation 6 of the primer? Once again, when working in US customary units don't forget to add the g_c multiplier of 32.174 lbm-ft/lbf-s^2. Also, don't forget that the pressures are in pounds per square inch rather than per square foot, i.e. one square foot = 144 square inches.

- a. 205.9 fps
- b. 4x10^12 mph
- c. 106.6 fps
- d. 52.2 fps

13. A normal shock has formed in front of a total pressure probe in a high-speed wind tunnel. The probe is measuring a total pressure of 10.00 psig. A static pressure tap just upstream of the shock is measuring 1.369 psig. What is the freestream Mach number of the flow ahead of the shock?

- a. 2.5
- b. 2.3
- c. 3.5
- d. 4.5

14. A projectile traveling with a Mach number of 0.85 is generally considered as flying in what compressible flow region?

- a. Hypersonic
- b. Supersonic
- c. Transonic
- d. Ultrasonic

15. What are some methods used to achieve spin stabilization?

- a. Rifling, angled fins, canted engines
- b. Either a duplex pair of angular contact bearings or a single four-point contact (x-type) bearing, but never plain bearings.
- c. Rifling, pistoling, and shot-gunning
- d. Thrust vectoring of engines

16. All else being equal, which of the following projectiles is expected to be the **LEAST** stable?

- a. One having the center of gravity is aft of the center of pressure
- b. One having the center of pressure is aft of the center of gravity
- c. One having the center of gravity and center of pressure located at the same geometric location
- d. One that is painted blue with green helical stripes and has tail fins.

17. With respect to a spin stabilized bullet with typical center of pressure and center of gravity orientation shot from a right twist barrel, which direction will the bullet tend to turn because of torque induced precession?

- a. Left
- b. Both answers A and D are correct
- c. There is too little information to answer this question
- d. Right

18. Relative to the stationary observer in space, what is the approximate tangential velocity of the earth at the equator in furlongs/fortnight (fur/ftn)? Earth's equatorial radius is approximately 3,960 miles, 1 mile is approximately equal to 8 furlongs, and a fortnight is equal to 14 days (336 hours).

- a. 24,000 apc/ly (attoparsecs/light-year)
- b. 0 fur/ftn
- c. 2,795,500 fur/ftn
- d. 2,400 fur/ftn

19. As many people have seen in the movie Superman, Superman was able to go back in time by flying around earth at apparently superluminal speeds. One consequence of his flight was that he reversed the direction of earth's spin. If earth rotated in the opposite direction that it currently does would a projectile move to the left or right of the intended target due to Coriolis effect in the northern hemisphere? Neglect any potential consequences associated with reversing earth's rotation and the ridiculousness of superman becoming an analog to tachyon particles.

- ○ a. Left
- ○ b. Right

20. Per equation 11 of the primer what is the drop factor for a projectile fired at 2500 ft/s with an azimuth angle of 100° and a latitude of 35°?

- ○ a. 1.252
- ○ b. 1.000
- ○ c. 1.083
- ○ d. 1.009